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DRAFT

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TO:MR. DAVID CROXTON
REGION 10, HW-106

ENFORCEMENT SENSITIVE

FILE COPY

FROM:ROBERT FARRELL

SUBJECT:TIDAL FLUCTUATION AND WATER ELEVATIONS WITHIN THE AQUIFER ARE TWO TIDAL TESTS NECESSARY AT PIER 91

The attached hydrographs of Figure 3.14 are from a tidal test done by OCC after a pump test. The test was performed to provide the lag time and tidal efficiency of each well in order to correct the drawdown curves measured from an earlier pump test at well EW-133-50. The analysis was not completed by OCC but has been completed as part of the review for the proposed ground water extraction system.

The one result that can be obtained from analyzing the tidal data is the determination of the ratio to T/S (transmissivity/storage) at each observation. This ratio can be solved if either T or S are assumed or solved for by some other means. In this case the ratio of T/S alone was useful in demonstrating that the aquifer has significantly different characteristics in only a few feet (10 to 15 feet in this case). For well EW-133-50 the T/S ratio varied from 92 to 138 ft. sq./min.. For 26-25 the ratio varied from 87 to 179 ft. sq./min. and for 26-50 the ratio was 391 to 804 ft. sq./min.. Well 26-50 (meaning the screen is located at a depth of 50 feet) has a significantly higher ability to produce water than do the other two wells. While this is important in the analysis of OCC's geology, it is not important in our discussion of the need for an additional tidal analysis at Pier 91. The important data is the variation in the wells and tidal responses that lead to the large range of T/S ratios seen at each individual well.

How does T/S relate to tidal efficiency

how does this imply or improve on 2 tests? what is the tidal impact on this ratio

The equation for determining the T/S ratio is

$$T/S = \frac{(x^{2})t}{4(\pi)(to^{2})}$$

(from:Bental, compiler, 1963, U.S.G.S. WATER SUPPLY PAPER 1536-I, pg. 309)

Where <u>x</u> is the distance from the shoreline, <u>t</u> is the period between the peaks or troughs, and <u>to</u> is the lag time between the maximum or minimum of the ground water cycle and the same maximum (peak at high tide) or minimum (trough at low tide) in the tidal cycle (all consistent units).

Figure 3.14 shows two tidal peaks and troughs. The time (t) between the two peaks is 810 minutes (13.5 hours) and the time between the two troughs is 700 minutes (11.66 hours). The lag times (to) for EW-133-50 range from 38 minutes to 50 minutes. The lag times (to) for well 26-25 range from 30 to 40 minutes and for well 26-50 the lag times range from 15 to 20 minutes. The tidal efficiency for EW-133-50 ranges from .49 to .56, for well 26-25 the tidal efficiency ranges from .49 to .56, and for well 26-50 the tidal efficiency ranges from .48 to .50.

To determine the ground water flow direction requires the determination of the ground water elevation at each well. Figure 3.14 provides the opportunity to determine the actual average water elevation at each well for cycles 1 and 2 and to compare the actual water elevation for the second cycle with a calculated water elevation for the second cycle. The change in the average elevation for the waterway between the cycle 1 and 2 is +.65'. To determine the predicted change in head the TE was multiplied times the change in the average head of the waterway. This change was added to the previous average water level at each well to determine the predicted water elevation. In all cases the predicted elevation is higher than the actual average ground water elevation.

	average elevation -- cycle 1	- cycle 2--	-- TE--	predicted change in head--	--predicted elevation
EW-133-50	0.05'	.25'	.56	.36'	.41'
WELL 26-25	1.25'	1.45'	.56	.36'	1.61'
WELL 26-50	2.1'	2.35'	.50	.32'	2.42'
WATERWAY	-.25'	.40			

The differences between the predicted water elevations and the actual water elevations are a few tenths of a foot after two tidal cycles. The differences between the actual water elevation at each well and the predicted elevations are introduced because of differences in the length of the two tidal cycles, changes in the elevation of each tidal cycle, changes in lag times, and possible barometric pressure changes.

Well 26-50 was an observation well during a 72 hour pump test. No response occurred during the pump test that was attributable to the pumping (the pumping well was EW-133-50) even though the pumping well was located at the same depth less than 15 feet away. During the test the tidal efficiency of well 26-50 ranged from .43 to .66 (compared to .48 to .50 earlier). The monitoring covered four tidal cycles (high and low tide being one cycle). The average head during each limb of a cycle was determined. The hydrograph of the average heads in the well still indicate influence for the tidal changes which are not consistant from one cycle to another. The average heads were further adjusted to account for the change in the average waterway elevation from a datum of 0 feet elevation using the tidal efficiency that was determined. The resulting curve shows the residual change in water elevation in well 26-50 through the monitoring period.

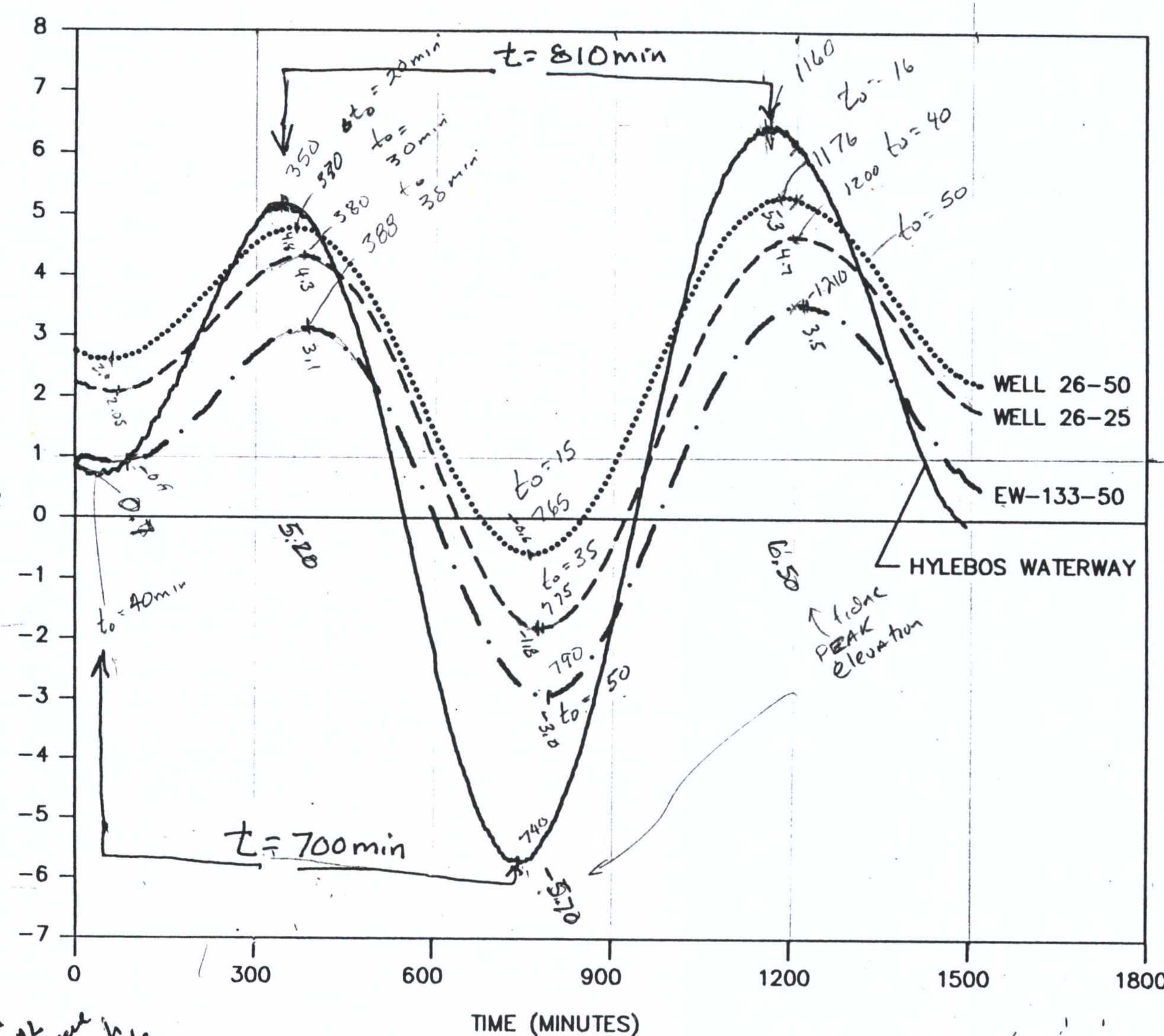
The time between peaks varies significantly between the different figures and during each monitoring period. On Figure 3.14 the time between peaks is 810 minutes while on attached figure 1 the time between peaks varies from 580 minutes to 895 minutes. It was not possible to exam the changes in lag time because there appears to have been a recording error on the tidal chart for the time that the cycle started.

CONCLUSION

The discussion presented above is for hydrographs from a site in Tacoma. It is unlikely that the hydrographs will have the same characteristics at Pier 91 because of the different configuration of the shoreline and a different location of the site in Puget Sound. The data presented indicates that it is not a simple matter of making a few measurements and adjusting the measurements to some datum or standard conditions. There are significant short term variations in the hydrographs that make the prediction of the water elevations difficult in the short term.

The hydrographs for the limited tidal cycles available indicate that just monitoring a single or a few tidal cycles is not sufficient to determine the average ground water elevation occuring at a well. The ground water elevation at the wells used had to be adjusted based upon a longer monitoring record that allowed the elevations to be adjusted to account for changes between tidal cycles. It is not clear that without the measurement of several complete tidal cycles at each well and in the waterway whether it would have been possible to determine the accuracy of the calculated water elevations.

The importance of these differences between the various tidal cycles will be determined by the ground water gradients at the site. If the gradients are very small an error in the estimated water elevation of a few tenths of the a foot will significantly effect the determined direction of ground water flow. If there are steep gradients, then the error between the actual ground water elevations and the estimated ground water elevations would have to be correspondingly larger to be significant.



ΔH (cycle #)	1	2	3
EW133	2.2'	6.1'	6.5'
26-25	2.2	6.1	6.5
26-50	2.2	5.4	5.9
WTR WAY	4.5	10.9	12.2

EW133	.49	.56	.53
26-25	.49	.56	.53
26-50	.49	.50	.98

TIDAL Efficiency for each cycle

Distance from Shoreline (X)
EW 133 = 60'
26-25 = 50'
26-50 = 53'

cycle #	1 (peak)	2 (Bottom)	3 (peak)
EW133-50	38	50	50
26-25	30	35	40
26-50	20	15	16

Lag times (minutes) (t_o)

$$T = \frac{x^2 S t}{4\pi t_o^2}$$

$t = 810$ min $= 13.5$ hr
$t = 700$ min $= 11.66$ hr

figure 3.14

STATIC GROUNDWATER ELEVATIONS VS. TIME
WELL 26-25 AND 26-50 WITH WATERWAY
EW-133-50 PRELIMINARY PUMPING TEST
Occidental Chemical Corporation—Taconma, Washington

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1002 (102) MAR 16/93 REV.0 (G-19)

TAKEN SOMETIME AFTER 2/17/93

Pumping Test EW133-50

Monitoring Well 26-50

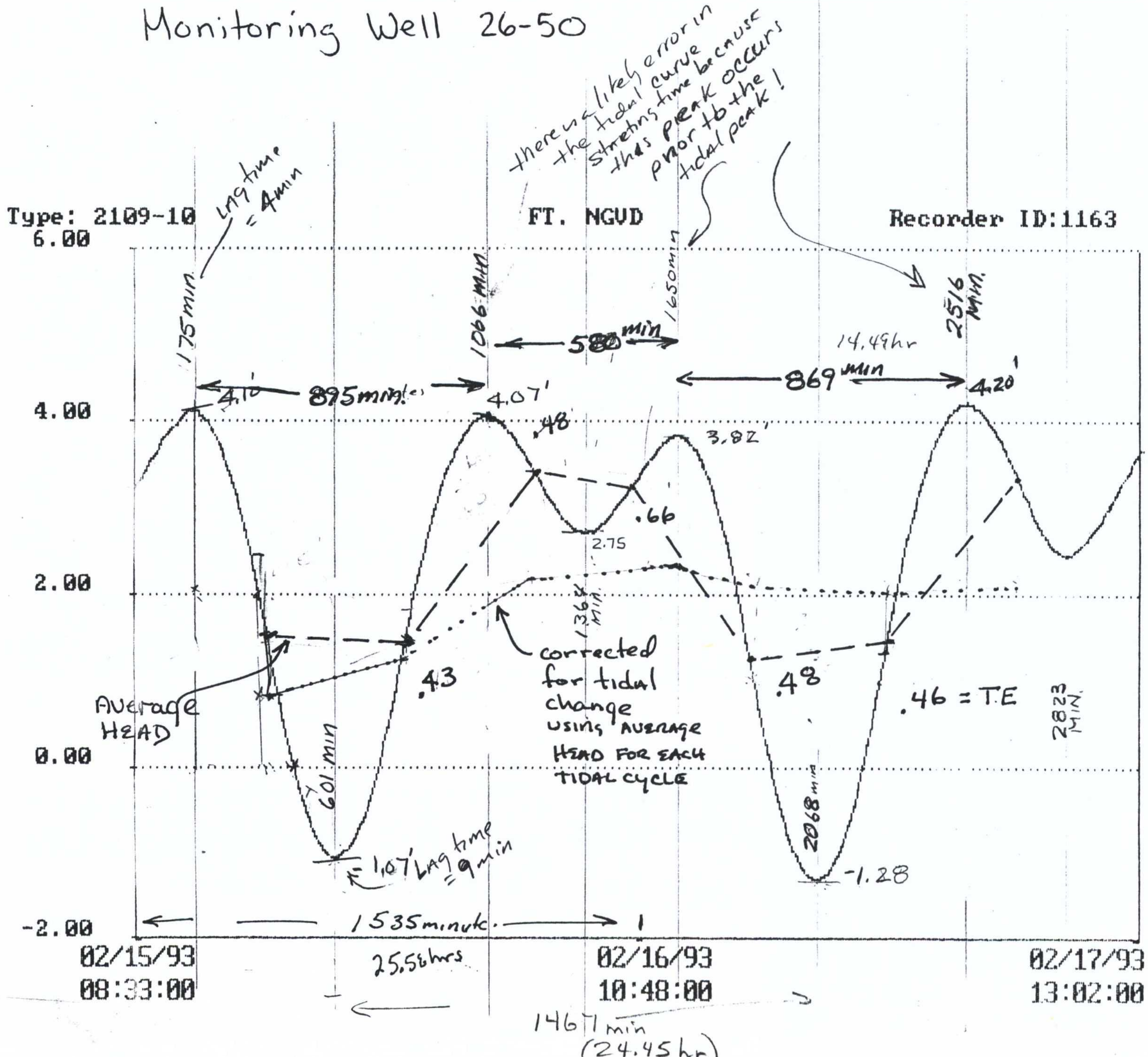

FIGURE 1